

# **The Inside Story on Tube Testers**

**The Challenge of Testing Tubes**

**MAARC RadioActivity**

**June 26-28, 2014**

# Presentation Perspectives

- **Experience and History**
- **Long Term Perspective**
  - **Discovery of tube characteristics**
  - **Long term decline of tube supplies**
  - **Increasing value of tube stocks**
  - **Increasing failure of metal to glass seals with time.**
  - **In the future, testing and importance of results will increase.**


## Recent Release Gary Steinbaugh

Detailed information on building vacuum tube and other electronics test equipment. Lots of great construction tips.

[www.greydenpress.com](http://www.greydenpress.com)

[http://www.greydenpress.com/Store/index.php?route=product/search&filter\\_name=steinbaugh](http://www.greydenpress.com/Store/index.php?route=product/search&filter_name=steinbaugh)

*MAKE YOUR OWN*  
**Tube Testers**



AND  
**ELECTRON TUBE**  
EQUIPMENT

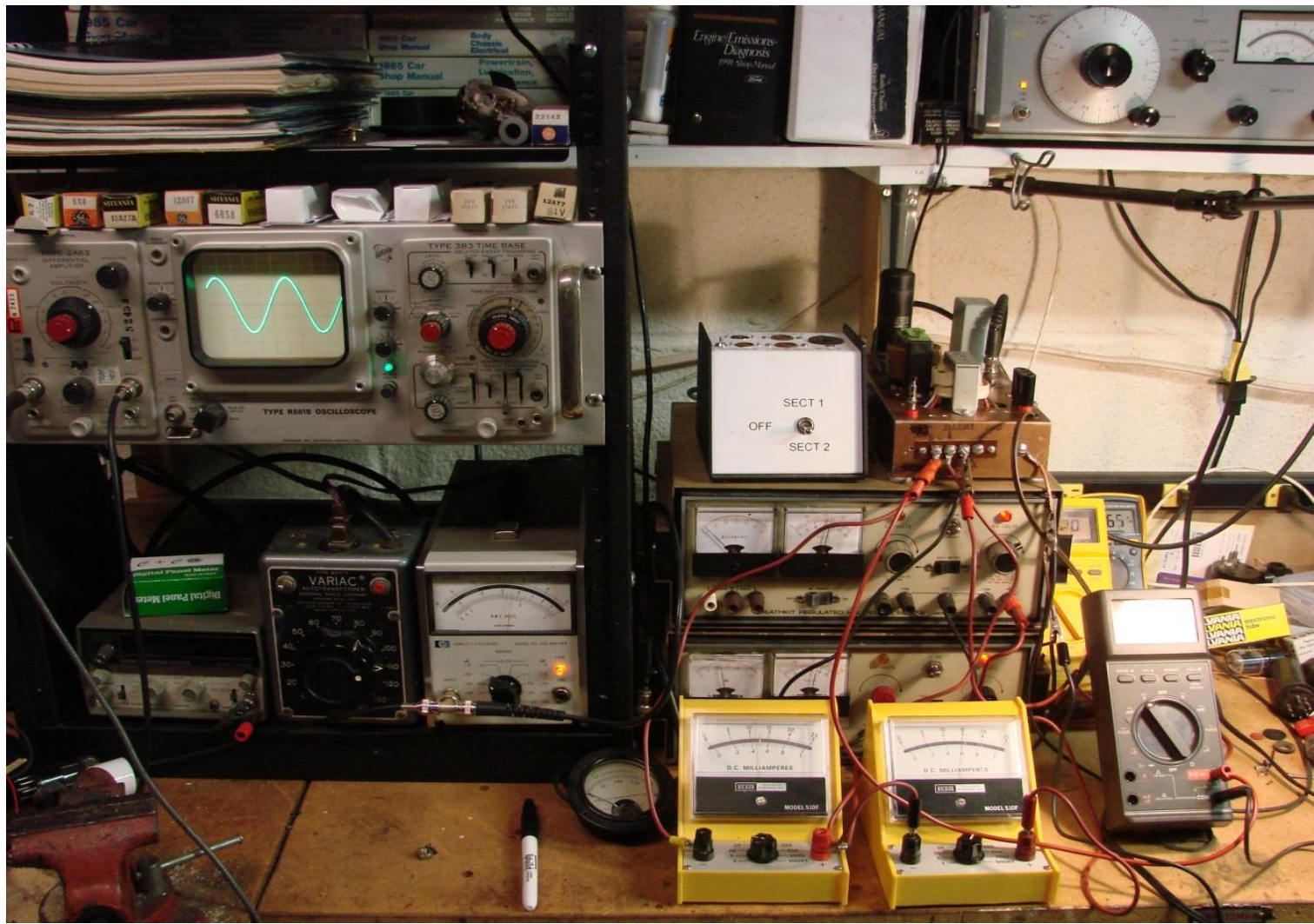
by Gary Steinbaugh, PE, AF8L

# **Brief Overview of Radio Age April 2014 Article**

- **The case for testing tubes**
- **The need for an Independent Evaluation Standard**
  - **Selection of Transconductance as the most important parameter for evaluation**
- **Construction of a Reference Tube Tester**
  - **Design and construction of the laboratory-level test fixture**
  - **Results, learnings and issues when testing tubes**

# Remainder of Presentation

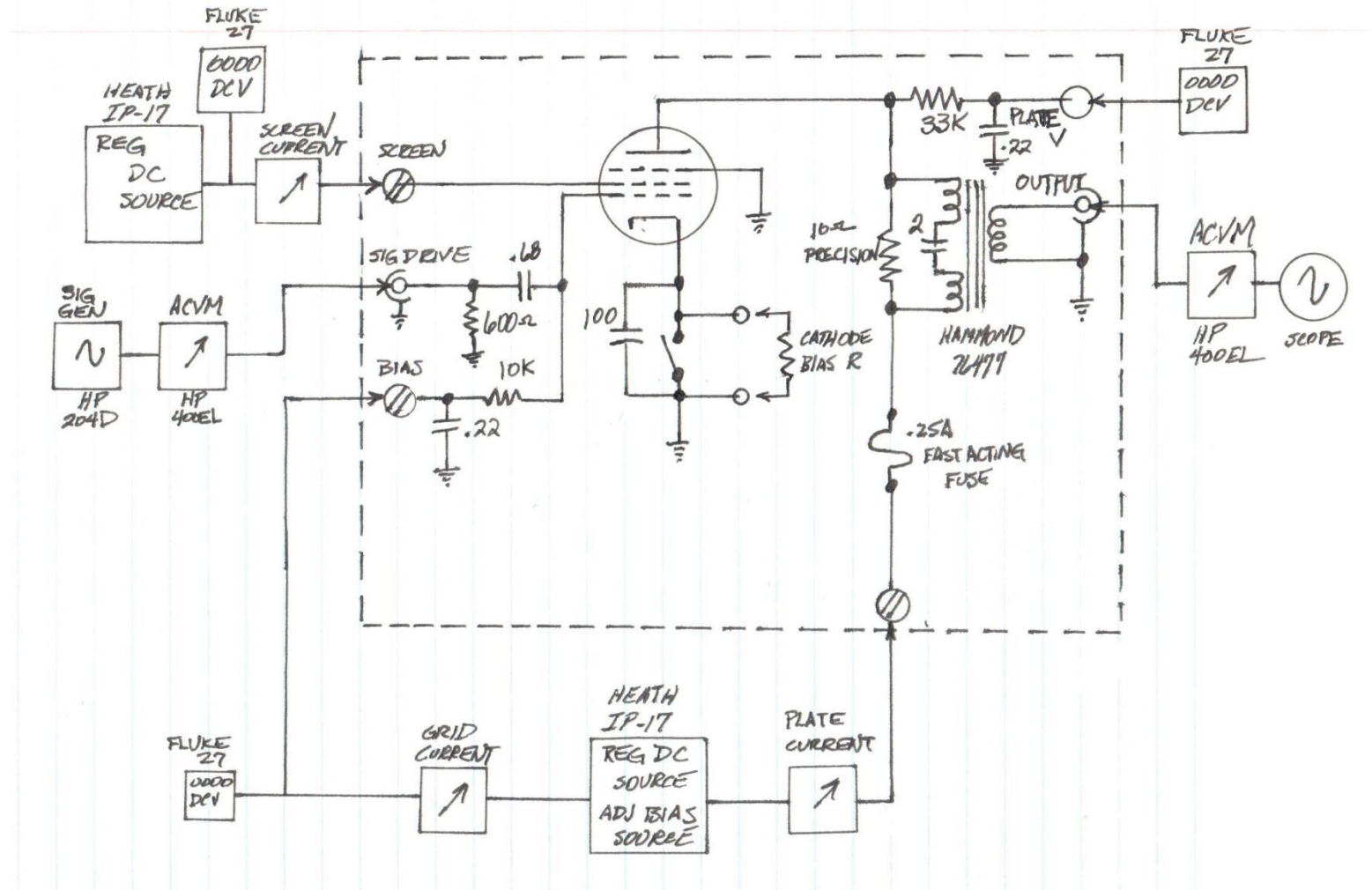
- **Overview of the Remaining Articles**
  - **What can we learn from the Laboratory Tester**
  - **The meaning and use of the term “NOS”**
    - **The most difficult tubes to test (maybe) 12AX7, 2A3, 8417**
  - **The Challenge of building a practical Tube Tester**
    - **Different designs, selecting from among the options**
  - **Different types of testers, advantages, disadvantages**
    - **Hickok and Western Electric**
    - **Triplett**



## The Haywire Tester

A laboratory grade tester for evaluation of vacuum tubes.

# Schematic of Lab Tester





## Tube Tester Chassis

**Filament Transformers and Multiple Socket Detail  
not Shown on Schematic**



# Tester's Unique Capabilities

- **Specific test conditions can be applied**
- **A tube can be operated for extended periods under selected test conditions**
- **Transconductance can be measured directly and repeatably**
- **Test conditions may be changed and observed in real time**
- **Filament voltage can be controlled and measured as well as “cathode activity”**

# Issues of Practicality

- **Detailed calibration requirements for each element**
- **Operator skill and attention**
- **Difficulty in testing many different types of tubes**
- **Possibility of damage to tester and tubes**
- **No commercial equivalent product available**
- **Length of time required for testing**

# Some Basic Elements of Tube Behavior

- **Variability of performance of NEW tubes**
- **Additional variability of tubes with unknown past**
- **Observe how transconductance varies with test conditions**
- **Electrical “Markers” of used tubes**
  - **Gas**
  - **Poor cathode activity**
  - **Inconsistency of test results**

# From the "Tube Collector", Tube Collectors Association December 2001, Vol. 3, No. 6 page 7

www.tubecollectors.org

## RCA PARAMETER LIMITS FOR NEW TUBES

Jerry Vanicek once suggested a check of the Dowd-RCA Archive for the official limits on tube performance. The following figures are from Standardizing Notices of '30s vintage (for the '20s oldies listed) and of '60s vintage for the later audio tubes.

These are, of course, limits for **new** tubes. As Bill Condon's article points out, they do not define "good" or "bad" for used tubes. Dealing with used goods, we have to allow for some slumping in use, which raises the question of how tube-tester makers defined "GOOD-?-BAD" readings. As for life tests, RCA's tests for civilian tubes relied on a simple power-output test ("expect 'x' watts' output after 500 hours") rather than specifying Gm or plate current.

The "bogie" figures for a tube might match the corresponding values in, say, the RC-15 manual, under the same test conditions (e. g., for the 71A and 6L6) but usually differed slightly. The factory limits for Gm might be symmetric about the bogie (for the 12A, 24A, and 27, say) but more often were not. (There's probably nothing in nature that would require symmetric limits.) An excessive Gm would be a worry to the factory: it might indicate a grid dangerously close to the cathode. The "customer" limits presumably allow for some knocking-about, tester error in the field, and a few hours of use. - LAS

Type	TRANSCONDUCTANCE ( $\mu$ S)					PLATE CURRENT (mA)					Measured at $E_p/E_g2/E_c$
	Cust. Min.	Fact. Min.	Bogie	Fact. Max.	Cust. Max.	Cust. Min.	Fact. Min.	Bogie	Fact. Max.	Cust. Max.	
10	-	1350	1600	1900	-	13	18.5	24	-	-	425 V / - / -35 V
12A	-	1300	1600	1900	-	4.5	6.2	8.5	-	-	135 V / - / -9 V
22	-	300	350	425	-	1.2	1.7	2.3	-	-	135 V / 45 V / -1.5 V
24A	900	950	1100	1250	1300	2.8	3.1	4.2	5.0	5.3	250 V / 90 V / -3 V
26	-	875	1075	1225	-	4.0	5.5	7.0	-	-	135 V / - / -9 V
27	815	850	1000	1150	1185	3.1	3.5	5.2	6.9	7.3	250 V / - / -21 V
40	-	300	400	525	-	0.40	0.45	0.90	-	-	135 V / - / -1.5 V
45	1550	1650	2100	2500	2550	20	22	30	38	40	250 V / - / -50 V
50	1550	1700	2100	2500	2550	40	42	55	68	70	450 V / - / -80 V
71A	1450	1550	1700	1850	1950	14.0	15.0	20.0	25.0	26.0	180 V / - / -40.5 V
199	-	350	425	570	-	1.6	2.4	3.5	-	-	90 V / - / -4.5 V
201A	-	600	725	825	-	-	1.7	2.4	3.2	-	90 V / - / -4.5 V
2A3	3200	3450	4000	4550	4800	22.5	28.0	40.0	52.0	57.5	300 V / - / -60 V
6BQ5	8300	8600	11,300	14,000	14,300	36	37	48	59	60	250 V / 250 V -7.3 V
6L6	5400	5550	6000	6450	6600	60	62	72	82	84	250 V / 250 V / -14 V
6L6GB		Same as for 6L6				62	64	72	80	82	Same as for 6L6
6L6GC	5300	5400	6000	6600	6700	58	60	72	84	86	Same as for 6L6
6V6GT	3500	3600	4100	5400	5500	33	34	45	56	57	250 V / 250 V -12.5 V
5881	5500	*	6100	*	6700	65	*	75	*	85	Same as for 6L6
7027A	5300	5400	6000	6900	7000	58	60	72	84	86	Same as for 6L6
6973	3800	4000	4800	5600	5800	57.5	60	65	-	-	250 V / 250 V / -15 V

\* 5881 was a purchased type; no manufacturing limit. Figures unavailable for 6550, another purchased type.

# GE 5751

## Characteristics Limits

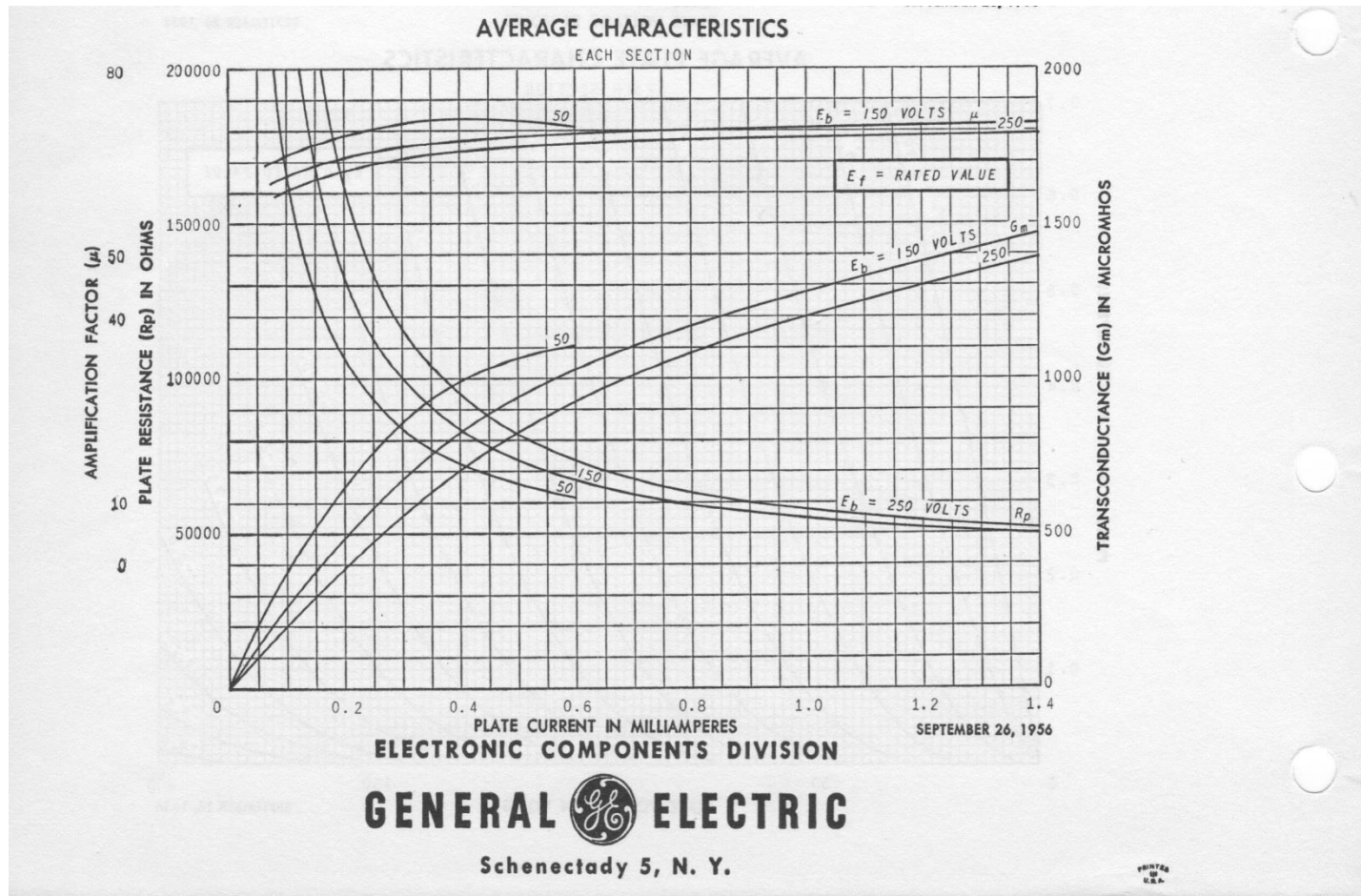
**5751**  
**ET-T1092A**  
 Page 3  
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### CHARACTERISTICS LIMITS

		Minimum	Maximum	
Heater Current E <sub>f</sub> = 12.6 volts	Initial	160	190	Milliamperes
	500-Hr	160	190	Milliamperes
	1000-Hr	160	190	Milliamperes
Plate Current, Each Section E <sub>f</sub> = 12.6 volts, E <sub>b</sub> = 250 volts, E <sub>c</sub> = -3.0 volts	Initial	0.4	1.8	Milliamperes
Plate Current Difference between Sections Difference between plate currents for each section at E <sub>f</sub> = 12.6 volts, E <sub>b</sub> = 250 volts, E <sub>c</sub> = -3.0 volts	Initial	...	0.6	Milliamperes
Transconductance (1), Each Section E <sub>f</sub> = 12.6 volts, E <sub>b</sub> = 250 volts, E <sub>c</sub> = -3.0 volts	Initial	900	1600	Micromhos
Transconductance Change with Heater Voltage, Each Section Difference between Transconductance (1) and Transconductance at E <sub>f</sub> = 11.4 volts (other conditions the same) expressed as a percentage of Transconductance (1)	Initial	...	15	Percent
Amplification Factor, Each Section E <sub>f</sub> = 12.6 volts, E <sub>b</sub> = 250 volts, E <sub>c</sub> = -3.0 volts	Initial	55	85	
Plate Current Cutoff, Each Section E <sub>f</sub> = 12.6 volts, E <sub>bb</sub> = 250 volts, E <sub>c</sub> = -10.5 volts, R <sub>L</sub> = 0.1 meg	Initial	...	10	Microamperes
AC Amplification, Each Section RMS Output Voltage from Fixed Input Signal E <sub>f</sub> = 12.6 volts, E <sub>bb</sub> = 100 volts, E <sub>cc</sub> = 0 volts, R <sub>L</sub> = 0.5 meg, R <sub>g</sub> = 10 meg, E <sub>sig</sub> = 0.2 volts, RMS	Initial	7.5	...	Volts

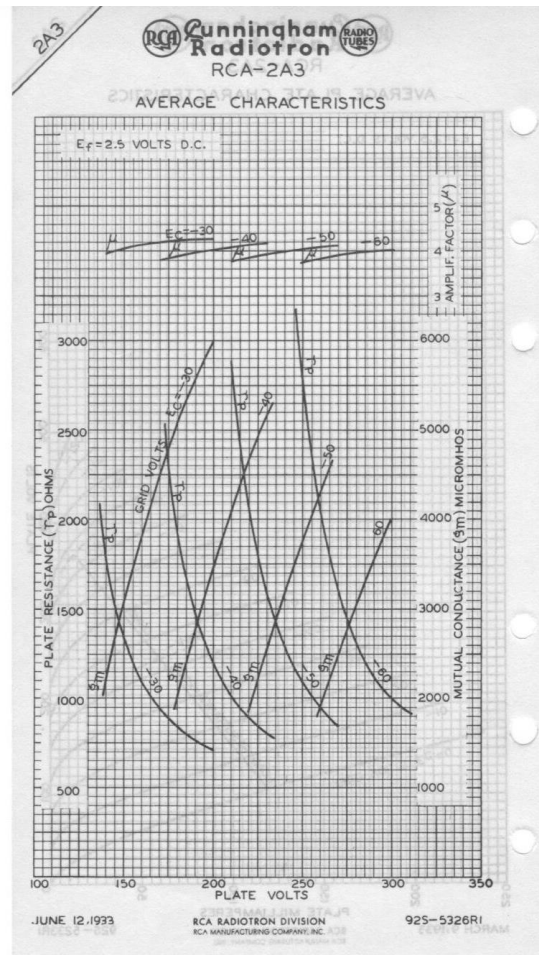
# GE 5751

## Average Characteristics



# 2A3 From 1933

“The Mother of High Fidelity”



# The Issue of NOS

- **Various interpretations and elements**
  - **What is meant by “Tests NOS”**
  - **Does it need an original carton? Swapping**
  - **Most of the time, you cannot be sure, but sometimes you can be quite confident**
- **The most difficult tubes to test and why**
  - **12AX7**
  - **2A3**
  - **8417, 6550, 6CA7**



# Tube Tester Manufacturer's Design Challenge 1

- **Tests**
  - **Shorts – A MUST**
  - **Leakage? Gas?**
  - **Quality for Diodes and Rectifiers**
  - **Performance for Amplifiers -**
    - **Transconductance (type), emission**
    - **Test conditions for measurement of tube quality**
- **Thousands of different types and arrangements**
  1. **VR tubes?**
  2. **Thyratrons?**

# **Tube Tester Manufacturer's Design Challenge 2**

## **Three Broad Categories**

### **➤ Emissions**

- **Tie all the elements together, test as a diode**

### **➤ “Proportional” Transconductance**

- **Hickok Barnhart Circuit**
- **Weston**
- **Many Other Hybrid Variations**

### **➤ Actual Transconductance**

- **Triplett 3423, 3444, 3444A**
- **Maxi-Matcher**
- **Amplitrex**

# **Manufacturers Dilemma Creates Your Smorgasbord**

- **Every choice had cost implications**
  - **Sliding scale – the better, the more expensive**
  - **Competitive marketplace**
- **Differentiation of product**
  - **Visual – Appearance - Reputation**
  - **Technical capabilities**
  - **Feel of the controls**
  - **Ease of use**

# **Decision Elements**

## **Current Environment View**

- **Features**
  - **Test capabilities - checklist**
  - **Tube types that can be tested**
  - **Ease of use**
  - **Scope of understanding of test results**
- **Cost**
- **Serviceability**
- **Resale**
- **Personal Preferences**

# **Focus on Hickok and Triplett**

**Hickok was/is the dominant factor in tube testers – for good reasons**

- **Multiple variations of testers in production at the same time for different markets**
- **Domination of military tester market**
- **Western Electric adoption of modified Hickok designs**
- **Test results from those testers has continuous credibility in the current market**
- **New implications in the current market**

# Simplified TV-7 Gm Test Circuit

From military manual, pg. 16

U.S Department of the Army,  
 Technical Manual TM 11-6625-274-35 dated 30 June 1960 to Change 5,  
 30 March 1976.

For brief review and discussion. A separate full page copy is provided for those who are interested in exploring further.

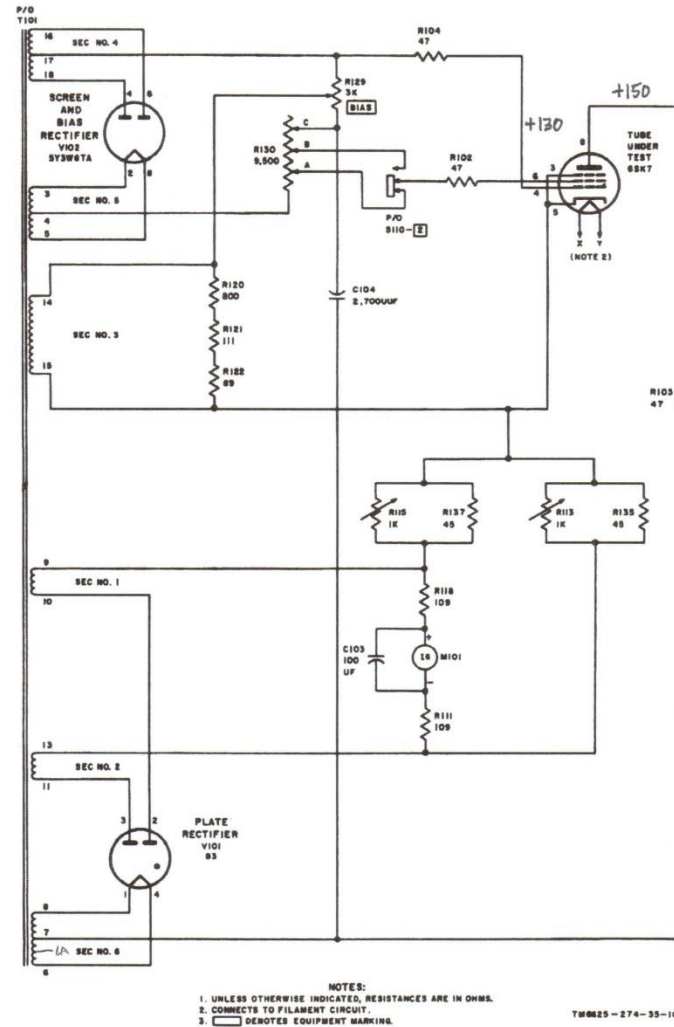


Figure 11. Simplified mutual conductance test circuit, TV-7D/U.

# The Hickok Barnhart Circuit

- **In one form or other, it is the basis for all of the testers made by Hickok up to the end of the tube era. Exception: Cardmatics**
- **Biggest difference is between models that use a twin variable Shunt (“English”) pot in the bridge (R115 and R113 in the schematic) and fixed resistances. Some can switch to either.**
- **When the Shunt pot is used for the gm test, the tester is more likely to be damaged by holding the gm control down for extended periods.**

# **Variety of Approaches Within the Hickok Product Line**

- All use the tube under test to drive the meter bridge directly**
- None of them yield gm readings that are taken under conditions comparable to manufacturer's stated conditions**
- Many of the different product line testers don't even agree with each other**
- Methods of calibration vary, some use check tubes, others do not.**



# A Quote of Significance

- **The 539 series, culminating in the 539C was the most sophisticated tester Hickok made (except Cardmatics)**
- **The most advanced were the KS-15750 for Western Electric with a separate DC bias supply, with no interaction between screen and bias voltage**

**From BSP Section 100-636-101 for the KS-15750, par. 1.09**

**“.....Since the indicated transconductance measured by this set is approximately equal, but not necessarily equal, to true transconductance, check tests made with this set should not be used as measures of new tube quality relative to manufacturer’s specifications.”**

# Hickok 6000A

- **Standard Hickok circuit with Shunt pot used in gm test**
- **Extremely sensitive shorts test via neon bulbs located under the hood in the center. Can give false short readings if leakages are present in switches or sockets.**
- **Uses 2.5V AC test signal, lower than TV-7 but still high.**
- **Requires calibration tubes be used**
- **Very versatile, with correct socket island, can test most modern tubes or very old tubes**
- **Most reasonably priced of the modern Hickoks**



## Hickok 6000A 1962 - 1969

**Serviceable utility tester. Almost too sensitive shorts test, can test later tubes (novar & compactrons) or earlier tubes by change of socket island. Uses Shunt control for gm tests, care must be used so not to damage the shunt pot.**

# Hickok TV-7, A, B, D

- **Popular tester for tube sellers and many others**
- **Very similar performance among them**
- **5 VAC signal on some tubes is excessive**
- **Widespread acceptance of test results**
- **Rugged beyond belief, parts generally available but expensive**
- **Does not test novar or compactron tubes**
- **Best and most expensive are the B and D**



## Hickok/Multi-Amp TV-7D in Final Checkout

Possibly the most ubiquitous tube tester in common use by tube sellers. Extremely durable, simple to operate, widely understood results. Issues are high cost and high signal test voltages on many small signal tubes.

# Triplett has Promise

- **Triplett has the architecture for a valid gm test**
- **Internal oscillator, conditions on tube close to manufacturer's specs, amplifier to drive meter**
- **Comes to grief because of poor regulation of filament and supply voltages. Setup conditions show alteration to compensate**
- **For some tube types, the Triplett can come quite close to actual gm**



# Westmore 501 aka Triplet 3444

Advanced Triplet tester with many positive features. Issues are inadequate regulation of filament and power supplies, parts availability. Its successor, the Triplet 3444A was Triplet's last.

# **Weston 981 Series (Heath TT-1)**

- **Has architecture that would allow modification to do true gm test**
- **Oscillator for drive signal**
- **But the tube being tested drives the meter directly. A driver amp would have to be added.**
- **DC test conditions are not comparable to tube specifications.**



# Possible Modification of Testers

- **Some modifications could be made to improve validity of test results**
- **If valid modifications were made that resulted in much better accuracy, who would believe them?**
- **Many testers have general acceptance of test results.**
- **Careful consideration must be given, you can't do much with a Hickok!**

# **Enough for Now**

## **Thanks for your Interest**

- **Future articles to go further into detail about issues and testers**
- **As time goes by, more information will become available, especially on lower level, more affordable testers**
- **Input welcome on which testers should be reviewed and other issues to address**
- **Weston, Jackson and Sencore are on the list**